Claims

1. A grinding machine having a conventional grinding wheel mounted on the machine wheelhead for movement parallel to the X and Z-axes of the machine (where the Z-axis is the axis of rotation of the workpiece and the X-axis is perpendicular thereto), wherein the wheel is mounted for rotation about an axis which remains parallel to the workpiece axis of rotation, X and Z-axis drive means are provided for moving the wheelhead relative to the workpiece parallel to the X and Z axes respectively, and control signals for determining the advance along the X and Z-axes are derived from a programmed computer which causes the wheelhead to advance towards and into engagement with a cylindrical surface of the workpiece along a line of action which subtends an angle of less than 90° to the Z-axis, the angle of approach being such as to simultaneously plunge grind an annular shoulder at an end of the cylindrical surface and to grind the cylindrical surface adjoining the shoulder during a single advance of the wheel towards the workpiece.

2. A machine according to claim 1 wherein the line of action achieved by the two X and Z movements of the wheelhead is 45° to the Z-axis.

3. A method of simultaneously cylindrical and face grinding a workpiece using a conventional grinding wheel wherein a wheelhead on which the grinding wheel is mounted is moved simultaneously parallel to and perpendicular to the axis of rotation of the workpiece so as to define a line of action along which the wheelhead moves towards and into engagement with the workpiece to perform a single plunge grind operation along that line of action, the amount of material removed from the cylindrical and radial faces of the workpiece by engagement with the grinding wheel being just sufficient to form the

shoulder and adjoining cylindrical surface in said single operation.

4. A method according to claim 3 in which the cylindrical surface which is to be ground extends over an axially greater distance than that corresponding to the width of the wheel, the cylindrical surface is ground in a conventional manner (such as by means of a series of adjacent plunge grinds) leaving an annulus of unground material which extends axially over a distance which is less than the width of the wheel from an adjoining radial shoulder which is to be ground to size, whereafter the wheelhead is advanced along a selected line of action so as to remove the unground annulus and grind the adjoining radial face to size in a single plunge grind along the said selected line of action.

5. A computer controlled grinding machine when programmed to advance a wheelhead, which carries a conventional grinding wheel mounted for rotation about an axis which remains parallel to the axis of rotation of a workpiece, along a selected line of action into engagement with the workpiece, wherein the line of action extends at an angle of less than 90° to the axis of rotation of the workpiece, so that unground material forming part of a cylindrical surface of the workpiece and an adjoining radial end face of the workpiece can be ground in a single plunge grind, in which the wheelhead moves along the said line of action into engagement with the workpiece and away therefrom after grinding.

6. A grinding machine in which a conventional grinding wheel is carried on a wheelhead which is itself adapted for movement along a first X-axis, a workpiece is rotated about a second perpendicular axis (the Z-axis) and is mounted on a carriage which is movable parallel to the Z-axis, and wherein the wheel rotates about an axis which remains parallel to the workpiece axis of rotation, an X-axis drive is provided for advancing and retracting the wheelhead parallel to the X-axis, a Z-axis drive

is provided for moving the carriage parallel to the Z-axis, and signals are derived for controlling the X and Z-axis drives from a computer which is programmed to generate appropriate X and Z-axis drive control signals to produce simultaneous movement of the wheelhead and workpiece, such that the movement of the wheelhead relative to the workpiece is along a line of action which subtends an angle with the Z-axis which is less than 90°, whereby the external cylindrical surface of the grinding wheel serves to remove material from the cylindrical surface of the workpiece and an adjoining circular face of the wheel engages a radial shoulder of the workpiece to grind the latter to size as the wheelhead is advanced along the said line of action.

7. A method of simultaneously grinding cylindrical and radial faces of a workpiece using a conventional grinding wheel in which the latter is advanced along a line which is perpendicular to the axis of rotation of the workpiece but which rotates about an axis which remains parallel to the workpiece axis of rotation throughout, and the workpiece is moved axially in a direction parallel to the axis about which the wheel is rotating, so that the movement of the grinding wheel relative to the workpiece is along a line of action which subtends an angle of less than 90° to the axis of rotation of the workpiece, so that the external cylindrical surface of the grinding wheel will remove material from the cylindrical surface of the workpiece to be ground, and an adjoining circular face of the wheel will engage and remove material from the radial face of the workpiece, and the angle made by the line of action relative to the axis of rotation is selected so that just the desired amount of material is removed from the said radial face, as the external cylindrical surface of the wheel removes material from the cylindrical face of the workpiece to bring it to size.

8. A computer controlled grinding machine in which a workpiece is movable by means of a carriage along an axis

parallel to the axis of rotation of the workpiece and perpendicular to the direction of advance and retraction of a wheelhead carrying a grinding wheel and in which the wheel is mounted for rotation about an axis which throughout remains parallel to the workpiece axis of rotation, when programmed to move the wheelhead and the workpiece carriage along the two orthogonal directions so as to produce a net movement of the wheelhead relative to the workpiece along a line of action which subtends an angle of less than 90°, relative to the axis of rotation of the workpiece.

9. A grinding wheel for use in the apparatus according to any one of claims 1, 2, 5 or 6, or in the method of any one of claims 3, 4 or 7, wherein the external edge face of the grinding wheel is formed so as to provide two grinding faces of which one parallel to the axis about which the wheel rotates, but which comprise first and second frusto-conical surfaces, the first frusto-conical grinding face being perpendicular to the second frusto-conical grinding face, and the grinding wheel is mounted for rotation about an axis which makes the same angle with the axis of rotation of the workpiece as the first frusto-conical surface makes with the axis of rotation of the grinding wheel, so that the said first frusto-conical surface will cylindrically grind the cylindrical workpiece surface, and the wheel is mounted on a wheelhead which itself is movable at least perpendicularly to the axis of rotation of the workpiece and can either be moved parallel to the axis of rotation of the workpiece, with separate drives to produce the said two perpendicular movements, to advance the grinding wheel to towards the workpiece along a line of action which is perpendicular to the axis of rotation of the wheel, or the workpiece is mounted on a carriage which itself is slidable parallel to the axis of rotation of the workpiece, and drive means is provided for moving the said carriage, and the wheelhead and carriage drive means are operated so as to achieve the same relative movement between the wheel and the workpiece, along the said line of action, so that however it

is moved, the wheel moves into engagement with the workpiece along the said line of action, and coolant is dispensed into the workpiece engaging region at least between the said second frusto-conical grinding surface and the radial shoulder of the workpiece being ground.

10. A method of simultaneously grinding cylindrical and radial surfaces of a workpiece in which a grinding wheel having two perpendicular frusto-conical grinding faces around its periphery is mounted for rotation about an axis which is co-axial with the coincident axes of the two cones of which the frusto-conical grinding surfaces form a part, the grinding wheel is mounted on a wheelhead so that one of the said orthogonal frusto-conical grinding surfaces will cylindrically grind a cylindrical surface of the workpiece, and relative movement is effected between the wheelhead and the workpiece so that the wheel engages the workpiece with the said one of the frusto-conical surfaces engaging to the cylindrical workpiece surface, and the other frusto-conical surface simultaneously engaging the radial surface which is to be ground, and a single plunge grind is performed along the line of action defined by the said relative movement such that just the required amount of material is removed from the two orthogonal surfaces of the workpiece as to leave both ground to size after the single plunge grind, and coolant fluid is directed into the region of engagement between at least one pair of grinding and workpiece surfaces.

11. A computer controlled grinding machine having a grinding wheel mounted on a wheelhead thereon for rotation about an axis which is coaxial with the coincident axes of two orthogonal frusto-conical grinding surfaces formed around the periphery of the grinding wheel, wherein the machine is programmed to produce relative movement between the wheelhead and the workpiece along a line of action which is perpendicular to the axis of rotation of the wheel so that a single plunge grind will remove material from a radial and a cylindrical surface

of the workpiece simultaneously.

12. A method according to claim 10 further comprising the step of dressing at least one if not both of the frusto-conical grinding surfaces, particularly that which engages a radial surface of a workpiece.